LCA Case Studies

Feasibility Study of Performing an Life Cycle Assessment on Crude Palm Oil Production in Malaysia

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Abstract

Background, Goal and Scope. The palm oil industry is one of the leading industries in Malaysia. With a yearly production of more than 13 million tons of crude palm oil (CPO) and plantations covering 11% of the Malaysian land area it is an industry to be reckoned with, also when it comes to environmental impacts. One way to describe and present the environmental impacts is through a life cycle assessment, LCA. This assessment aims to introduce the concept of LCA and perform a screening LCA on crude palm oil production in Malaysia including the stages of plantation, transport and milling. The assessment is largely based on general data and is thus meant to function as an indication of the environmental threads posed by CPO production and as a guideline to CPO producers and local universities on how to perform an LCA on a palm oil scenario. Due to the general data background the results of this report should not be quoted directly for decision making. The Functional Unit, to which all masses and emissions in this assessment have been adjusted, is the production of 1000 kg of CPO in Malaysia.

Method. Initially an overview of palm oil production was obtained and the outlines and borders of the assessment were determined along with the specific goal and scope of the assessment. The data for the assessment was collected from three different sources:

1. Earlier studies and statistics on palm oil production in Malaysia
2. Studies on similar processes, when palm oil related processes were not available
3. General data from the SimaPro 5 database

The European Eco-Indicator 99 method and European databases included in the LCA software SimaPro 5 have been used for the impact calculations.

Results and Discussion. The impact processes related to the plantation are the on-site energy use (mainly diesel) and the production of artificial fertilizer. Pesticide use contributes a minor impact due to widely used integrated biological poet management. For transportation the only impact is from combustion of diesel and at the mill the boiler is the sole significant contributor – positively through electricity production and negatively by emissions from the boiler. Impacts from POME (Palm Oil Mill Effluent) are not dealt with in the main assessment, but touched upon in alternative scenarios. The results clearly show that fertilizer production is the most polluting process in the system followed by transportation and the boiler emissions at a tie. The most significant impacts from the system are respiratory inorganics and depletion of fossil fuels, of which the boiler emission is the main responsible for the prior and fertilizer production and transportation are responsible for the latter. It is also evident from the results that crude palm oil production is a significant environmental impact generator in Malaysia due to the vast production quantities. Alternative scenarios revealed that there are significant impact savings to be made by introduction of environmental investments, both regarding the overall impacts and in particularly regarding CO_2 emissions.

Conclusion. A screening LCA was successfully conducted on the Malaysian crude palm oil production thus promising potentials for the palm oil industry to conduct their own inventories and assessments using specific company data.

Crude palm oil production in Malaysia is responsible for app. 3.5% of the total environmental impacts in the country and must thus be given attention to reduce impacts. Alternatives such as optimized use of organic fertilizer, environmentally friendlier artificial fertilizer production, rail transport, approved filters at the mill boiler stack and biogas harvest from POME digestion must thus be promoted in the industry.

Recommendations. The Malaysian palm oil industry should take steps towards introducing LCA. Exhaustive inventories are likely to open the eyes of many companies towards implementing environmental investments and improve the international competitiveness. In order to retrieve results with a greater accuracy in the future, databases must be created containing life cycle data from Malaysian scenarios and normalization and weighting factors must be designed to reflect Malaysian conditions. The Malaysian authorities must create incentives through increased tariffs on electricity and diesel and/or financial support for cleaner technology investments.

Keywords: Crude palm oil; Malaysia; palm oil mill; palm oil plantation

Introduction

The Malaysian palm oil industry has grown rapidly over the years to become the world's largest producer and exporter of palm oil and it products. In 2003 more than 3.79 million hectares of land were under oil palm cultivation (MPOB 2004), occupying more than one-third of the total cultivated area in Malaysia and 11% of the total land area. The industry has contributed significantly towards the country's foreign exchange earnings and the increased standard of living of its population.

In 2003, 360 palm oil mills were in operation in Malaysia processing 72 million tonnes of fresh fruit bunches, FFB. In

the same year production of palm oil in Malaysia had reached 13.35 million tonnes of crude palm oil and 1.64 million tonnes of crude palm kernel oil which was an increase of app. 12% over that of the previous year. Malaysia's production of palm oil in 2003 contributed to about 49 percent of world palm oil output and 8.9% of world output of the 17 major oils and fats bringing Malaysia an export revenue of RM 26.15 billion including export of oil related products. The world demand for palm oil is expected to increase due to the competitive prices and energy efficient production of palm oil along with the growing markets of e.g. China and India (MPOB 2004).

Being involved in 3 sectors, namely agriculture (plantation), transport and industry (milling) the production of palm oil faces a triple environmental challenge which must be monitored and dealt with. With a vast use of fertilizer in the plantations, poorly maintained transportation trucks and air emissions and wastewater from the mill, the industry has both environmental responsibilities to live up to and money to save by making the right technological investments and incorporating environmental management.

Within the last few years, environmental issues are increasingly becoming more important in Malaysia and the world over. The palm oil industry is aware of the environmental pollution and is striving towards quality and environmental conservation through sustainable development and cleaner technology approach. However, continuous environmental improvements are necessary and to remain competitive the oil palm industry must be prepared for new challenges ahead.

Self regulated environmental management tools like the ISO 14000, EMAS and Life cycle assessment could be adopted by the palm oil industries to structure their environmental efforts to the benefits of themselves and the environment.

1 Goal Definition

This screening LCA has the purpose of promoting LCA through illustrating the functions and possibilities of LCA as a methodological assessment/decision tool in the palm oil industry and uncovering the environmental consequences and heavy-impact stages/processes of crude palm oil (CPO) production in a life cycle perspective. Further more, alternatives to the heavy-impact processes will be assessed.

The assessment is intended for use amongst environmental managers and policy makers in the palm oil industry and as a general environmental guide for oil palm plantations and palm oil mills. It is also the hope of the commissioner that this study will contribute to enhanced LCA use and research in academic environments.

As this LCA is intended mainly as a promotional insight into the possibilities of LCA on palm oil production, it is important to hold in mind that it presents an overview of the present situation and should be used as a guide. Due to the general data background the results of this report should not be quoted directly for decision making. It is rather more appropriate to be used as an inspirational platform onto which detailed and broad spectre assessments can be produced.

2 Scope Definition

The scope of this assessment evolves around the environmental consequences of production of crude palm oil (CPO) in Malaysia. The main life cycle stages of palm oil include oil palm plantation processes (growth and harvest), milling, use and disposal. Palm oil has a wide variety of uses in both edible and non-edible aspects and thus diverse disposal procedures depending on the product. These stages in the palm oil life cycle are therefore easier dealt with in LCAs for the respective products. Emphasis in this assessment is thus put solely on the production of CPO; that is plantation processes, transportation and milling. In other words a cradle to gate study.

The functional unit (FU) to which all masses and emissions in this assessment have been adjusted is the production of 1000 kg of CPO (the output from 5000 kg of fresh fruit bunches, FFB) in Malaysia.

As impacts from clearing of jungle are not easily quantified and subject to harsh discussions, it has been included solely qualitatively in this assessment. The cradle of the assessment is thus the start-up of the plantation whereas the grave is the final production of CPO.

This assessment uses the LCA software SimaPro 5 and the LCA method Eco-Indicator 99. The impact assessment parameters are listed in **Table 1**. The final human health impact is derived by adding up the DALY values; the ecosystem quality value is derived by adding up the PDF values (PAF = PDF/10) and the resources depletion is derived by adding up the SE values.

Table 1: Assessment parameters

Impact Category	Characterization	Damage Category
Emissions		
Carcinogens	DALY/kg	Human Health
Respiratory organics	DALY/kg	Human Health
Respiratory inorganic	DALY/kg	Human Health
Climate change	DALY/kg	Human Health
Radiation	DALY/kg	Human Health
Ozone layer	DALY/kg	Human Health
Ecotoxicology	PAF*m^2*year/kg	Ecosystem Quality
Acidification	PDF*m^2*year/kg	Ecosystem Quality
Eutrophication	PDF*m^2*year/kg	Ecosystem Quality
Land use		
Decreased diversity	PDF*m^2*year/kg	Ecosystem Quality
Resource depletion		
Metals/Minerals	SE/kg	Resources
Fossil fuels	SE/kg	Resources

(Goedkoop & Spriensma 2001)
DALY: Disability Adjusted Life Years (Years of disabled living or years of life lost due to the impacts)
PAF: Potentially Affected Fraction (Animals affected by the impacts)
PDF: Potentially Disappeared Fraction (Plant species disappeared as result of the impacts)
SE: Surplus Energy (MJ) (Extra energy that future generations must use to excavate scarce resources)

Table 2: European normalization and weighting factors

Damage category	Normalization		Weighting
		Reciprocal [a]	
Carcinogens	$2.00 \cdot 10^{-3}$	500	
Respiratory organics	$1.07 \cdot 10^{-2}$	93.5	
Respiratory inorganics	$6.84 \cdot 10^{-5}$	14619	
Climate change	$2.39 \cdot 10^{-3}$	418	
Radiation	$2.68 \cdot 10^{-5}$	37313	
Ozone layer	$2.19 \cdot 10^{-4}$	4566	
Human Health	$1.54 \cdot 10^{-2}$	65.1	400
Ecotoxicity	811	$1.23 \cdot 10^{-3}$	
Acidification/Eutrophication	375	$2.67 \cdot 10^{-3}$	
Land use	3995	$2.50 \cdot 10^{-4}$	
Ecosystem Quality	5130	$1.95 \cdot 10^{-4}$	400
Minerals	148	$6.76 \cdot 10^{-3}$	
Fossil fuel	8260	$1.21 \cdot 10^{-4}$	
Resources	8410	$1.19 \cdot 10^{-4}$	200

(Goedkoop & Spriensma 2001a)
[a] Used for calculations by Eco-Indicator 99

After characterization and damage assessment the values will undergo normalization, which will allow comparison of the impact and damage categories to determine within which categories the main impacts occur. This is done by relating the impacts to the impacts from one person in one year; a so-called person equivalent

Weighting of the normalized values against the importance of the respective impact categories will allow for addition of the categories into one final impact value for the system.

As no Malaysian normalization and weighting factors exist, European values have been adopted in the assessment. Using European values brings significant uncertainties to the results of the analysis. The results must thus be handled critically. **Table 2** lists the normalization and weighting factors used in the assessment.

3 Methodology

Initially an overview of palm oil production was obtained and the outlines and borders of the assessment were determined along with the specific goal and scope of the assessment.

The data for the assessment was collected from three different sources:

1. Earlier studies and statistics on palm oil production in Malaysia
2. Studies on similar processes, when palm oil related processes were not available
3. General data from the SimaPro 5 database

Based on the collected data a description of the system was made including the background and quantities for all processes, inputs and outputs, which were ultimately summarised in the life cycle inventory, LCI. Conducting an LCA is an iterative process in which data collection lasts throughout the project. All collected data was computed into SimaPro 5, which calculated the impacts by means of the Eco-Indicator 99 method and the LCI dabase in the software.

4 Overview of the System and Life Cycle Inventory

The system includes the three stages of plantation, transportation to the mill and milling. **Table 3** depicts general plantation values. **Table 4** provides an overview of the processes in the respective stages along with the system flow in **Fig. 1**. **Table 5** lists the immediate inputs and outputs from the system, the LCI.

This assessment has aimed to include the most significant processes of the CPO production. Due to limitations in the LCA database in SimaPro 5 two processes that may have had influence on the results have been omitted. These processes are the conversion of jungle to plantation and the possible releases of untreated (high BOD) palm oil mill effluent, POME, to the waterways. Another significant parameter omitted is the production of methane (biogas) from the anaerobic digestion of POME. It is not known how many mills release the biogas directly to the atmosphere, how many, which flare the gas and how many, which utilize the gas for electricity production. This global warming impact has thus been omitted from this paper. CO_2 discussions and results will be available in Yusoff and Hansen (2004) to be published in 2005. None of the pesticides used on Malaysian palm oil plantations are recognized by SimaPro 5. Pesticides may thus have impacts that are not considered here. However, sources claim that pesticides are used in so relatively small doses at the plantations, which have generally introduced integrated (biological) pest management, that the impacts are generally limited to the person spreading the pesticide.

The impacts from the nursery stage proved to be negligible compared to the impacts from the full life cycle of the palms.

Table 3: General plantation data

General Plantation size	1000–6000 ha
Palm lifetime	25–30 years
FFB producing lifetime	22–27 years
Palms per ha	140 palms
FFB per palm per year	140 kg
FFB per ha per year	19 ton
FFB to produce 1000 kg CPO	5000 kg
Area to produce 1000 kg CPO/year	0.25 ha
Frond residues from 0.25 ha/year	1800 kg
Old palm stems from 0.25 ha/year	40 kg
Yearly production of CPO in Malaysia	13.4 million ton (2003)

(Hirsinger et al. 1995, MPOB 2004)

Table 4: Processes in the respective stages of the system

Stage	Processes	Specifically	Reference
Plantation	Land clearing	Included qualitatively in discussion	
	Nursery stage	Artificial fertilizer use (proved negligible)	von Uexkull 1992
	Energy use at plantation	Electricity use at office Diesel use for machinery	Amir 2004, Wood & Corley 1991
	Fertilizer/pesticide use and emissions	Artificial fertilizer Organic fertilizer Pesticides	Mutert & Fairhurst 1999, Mutert & Fairhurst 1999, Singh 2001, Cheng Hai 2000
	Production of fertilizer	Chemical use Energy use	Davis & Haglund 1999, Wood & Corley 1991
	Reuse of organic litter	As mulch	Hirsinger et al. 1995, Mutert & Fairhurst 1999
Transport	Diesel use and emissions		Amir 2004, SimaPro 5
Mill	Boiler stack emissions		Resource Sys. Group 2001
	Electricity production	Substitution of conventional electricity production	Tennamaran 2001, JEMAI 1999
	Reuse of organic residues	POME [a], EFB [b], Shells, Fibre	Hirsinger et al. 1995, Mutert & Fairhurst 1999
	Biogas production	Not included in the main assessment, but included in the alternative scenarios	Matsushita 2003
	Methane emissions from POME digestion	Not included in the main assessment, but included in the alternative scenarios	Shirai 2001, Wenzel et al. 1997
	POME discharge to waterways	Not included due to limitations in SimaPro 5 (no BOD/COD calculations)	

[a] Palm Oil Mill Effluent (Liquid residue from the oil extraction. High organic content)
[b] Empty Fruit Bunches (Waste from the stripping of fruits from the FFB (Fresh Fruit Bunches))

Table 5: LCI – Inputs and outputs of the system

Process	Input			Output			
		Quantity	Unit		Quantity	Unit	Fate of output
Plantation:	**Artif. Fertilizer**			**FFB**	5000	kg	CPO production
Planting,	N	24	kg	**Emissions**			
Growth,	P_2O_5	7	kg	N	5	kg	Soil/water
Harvest	K_2O	43	kg	P_2O_5	2	kg	Soil/water
	MgO	12	kg	NO_2	0.5	kg	Air
	Energy	2690	MJ	SO_2	0.2	kg	Air
	Diesel	34	L	Pesticides	0.4	kg	Soil water
	Electricity	1345	MJ	Pesticides	0.1	kg	Air
	Pesticides	2	kg	**Energy emissions**	*		
	Energy	–	MJ	**Organic litter**			
	Chemicals	–	kg	Fronds	1800	kg	Mulch at plantation
	Org. fertilizer			Stems	40	kg	
	N	8	kg				
	P_2O_5	3	kg				
	K_2O	28	kg				
	MgO	5	kg				
	Water	–	L				
	Energy						
	Diesel	17	L				
	Electricity	2	MJ				
Transport	Diesel	30	L	Emissions	*		Water, soil, air
Mill	**FFB**	5000	kg	**CPO**	1000	kg	Refining/use
(CPO production)	Chemicals	negligible		**POME**	2500	kg	Fertilizer at plantation
	Water	–		**Organic litter**			Mulch at plantation
	Energy			EFB	1170	kg	
	Electricity	320	MJ				Burn for steam production
	Steam	8100	MJ	Fiber	780	kg	Burn for steam production
							CPKO
				Shell	380	kg	Air
							Water, soil, air
				Kernel	330	kg	Sterilization
				Evaporation	590	kg	
				Electricity	590	MJ	Air
				Steam	8100	MJ	Air
				Stack Emissions**			Air
				NO_x	0.64	kg	Air
				CO	5.64	kg	Air
				Particles	1.38	kg	
				SO_2	0.02	kg	Air/generator
				TOC	0.05	kg	
				Biogas from POME digestion	70	m^3	

Please refer to Table 4 for references.
All values are related to the production of 1 ton of CPO ~ 5000 kg FFB ~ 0.25 ha/year.Energy values are given in on-site energy consumption, not primary energy. The full LCA calculated by SimaPro 5 including life cycle impacts is too comprehensive to be listed.
*) Numerous emissions (calculated by SimaPro 5)
**) Based on stack emissions from small wood boilers

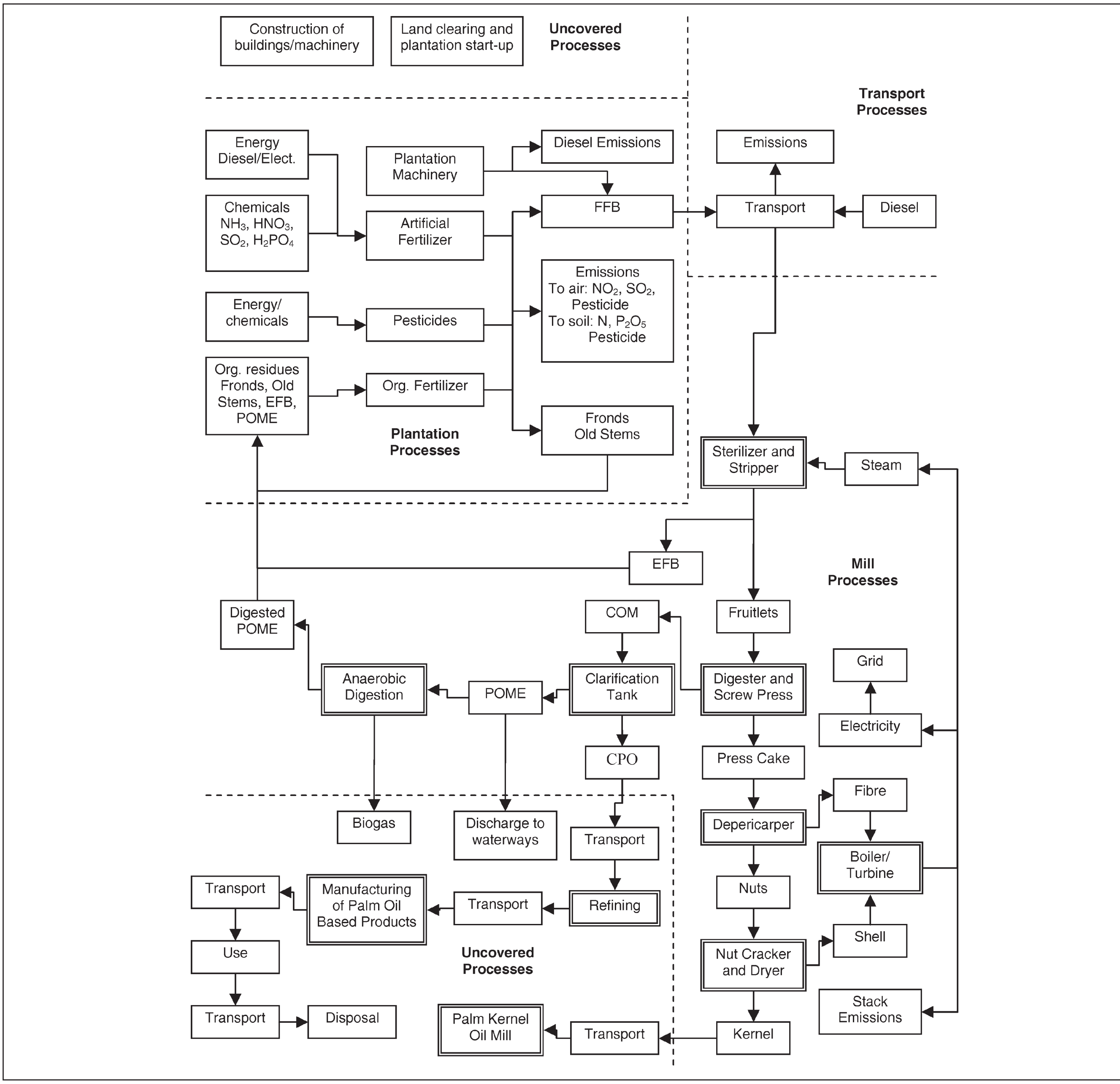

Fig. 1: Flow of the system

5 Life Cycle Impact Assessment (LCIA)

The damage impact results are given in weighted values in **Fig. 2**. It is evident that respiratory inorganics and fossil fuel depletion constitute the heaviest environmental burdens in the system. Whereas boiler emissions from the mill make up most of the respiratory inorganics, the fossil fuel depletion is dominated by fertilizer production related to the plantation stage. Due to the net electricity production from the mill substituting conventional electricity production there is a negative mill value under fossil fuel depletion. The impacts from the boiler emissions are mainly due to particles, whereas the main impacts from the fertilizer production are from energy use.

Climate change and acidification/eutrophication play less significant roles in the system. The roles of these two impacts would, however, be more significant if methane emissions from anaerobic POME digestion ponds and uncontrolled discharge of untreated POME to the waterways were included in the assessment. It should be noted that climate change is weighted lightly by Eco-indicator 99 due to the inadequate precision in models estimating global warming impacts.

In order to get a clear overview of which stage contributes most to the environmental impacts, the results are presented per stage in **Fig. 3** and the impact categories are categorized into damage categories (see Table 1) to enhance the overview. From the table the plantation stage clearly stands out. The impacts from the plantation are mainly caused by the production of fertilizer. The total score of 61.2 shows that the production of one ton of CPO is comparable to just over 6%

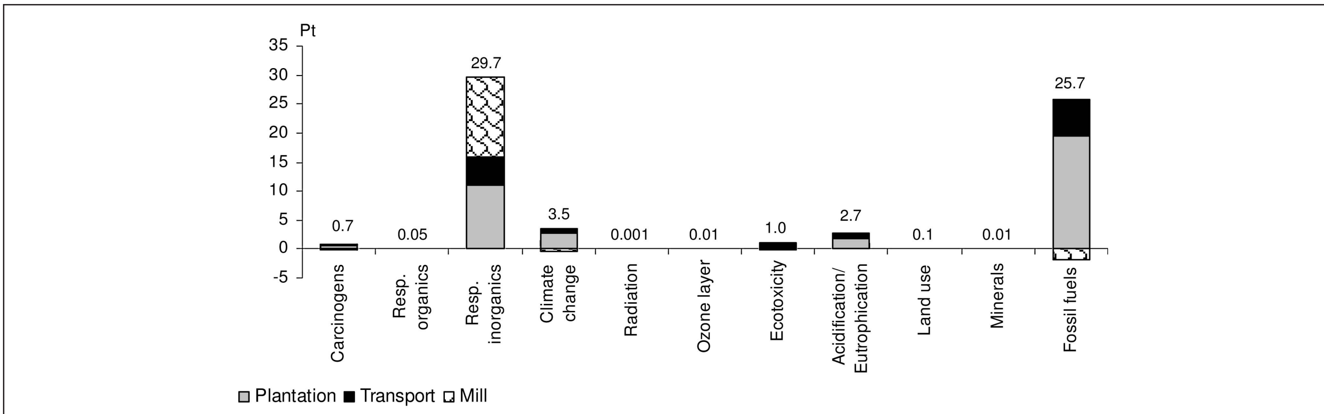

Fig. 2: Results (weighted values). Pt: Eco-Indicator 99 point. 1 pt ~ impacts from one-thousandth person per year

of the environmental impacts produced by one person in one year. With 13.4 million tons of CPO yearly and 23.5 million people in Malaysia, CPO production is thus responsible for 3.5% of the total environmental impacts in Malaysia.

Alternative Scenario. In order to quantify the impacts of possible improvements to the system, an alternative scenario has been created.

In the alternative scenario the fertilizer production has been optimized (20% less chemicals and 33% less energy), the re-use of POME and EFB as fertilizer has been enhanced by 50%, the transportation from plantation to mill is done by rail, the particle emissions from the mill boiler have been reduced by 50% and the anaerobic POME digestion is done in tanks with biogas collection and subsequent electricity production. It should be noted that the mentioned reduction percentages are assumptions meant to illustrate possible examples of optimization. They are not supported by references.

Fig. 4 depicts the result from the alternative scenario in which the impacts from transportation have become insignificant and the substitution of conventional electricity production by the electricity production from the mill boiler and the biogas from POME digestion has become an influential positive factor.

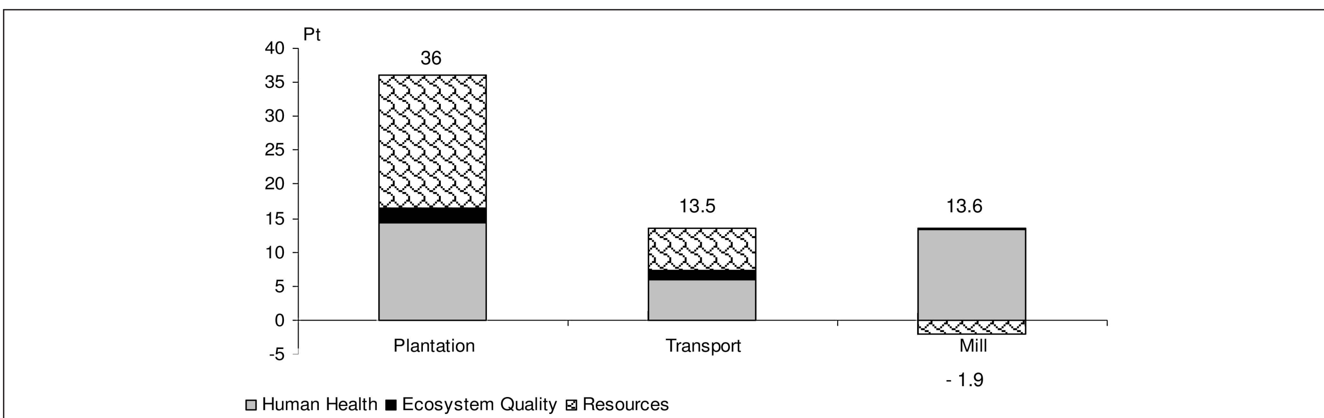

Fig. 3: Results per stage

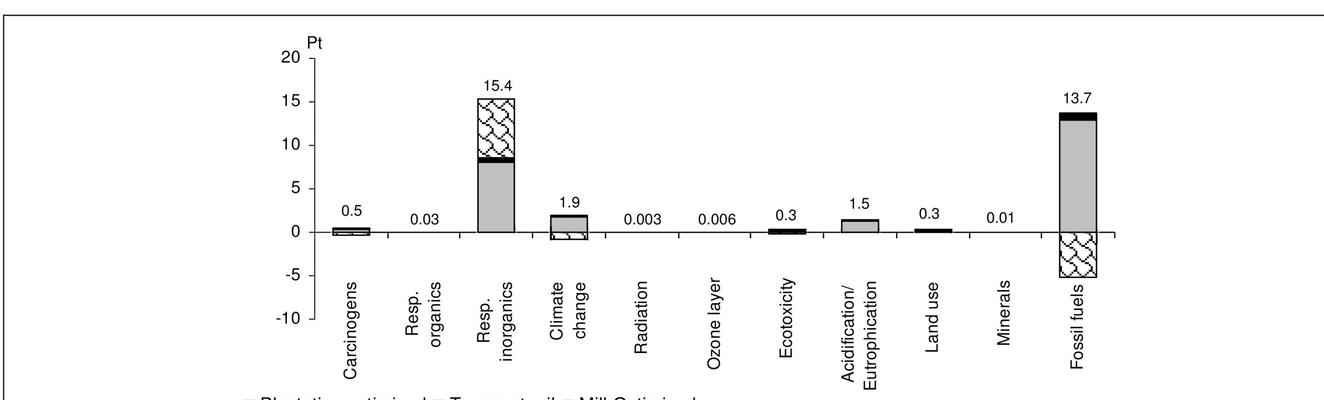

Fig. 4: Results from the optimized system (weighted values)

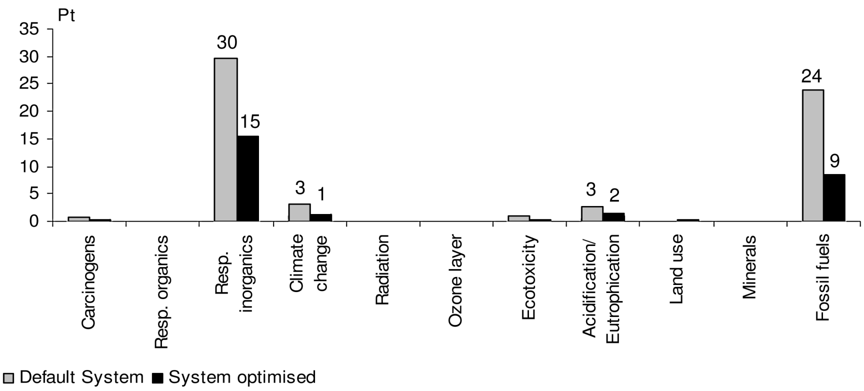

Fig. 5: Comparison between the default and the optimized system (weighted values). Total score: Default system: 61.2 pt; Optimised system: 24.8 pt

Fig. 5 is a comparison between the default system and the alternative system, which clearly shows the impact savings of the alternative scenario.

6 Discussion and Conclusions

The assessment has been carried out on three stages in the life cycle of crude palm oil, namely plantation, at which the machinery energy use and the fertilizer production are significant; transport, which deals with diesel consumption; and milling, from where boiler emissions must be taken seriously, but where produced electricity can substitute conventional electricity production and function as a positive impact.

A sensitivity and uncertainty analysis was carried out qualitatively and suggests that the specific result values must be adapted with caution due to use of general data and European normalization/weighting factors, but that the general conclusions of the assessment are not likely to be affected by the uncertainties.

It is strongly indicated from the results that palm oil production constitutes a significant environmental impact in Malaysia and that the fertilizer production is the heaviest single process. Among the impact categories, respiratory inorganics and fossil fuel depletion are the most significant with global warming and acidification/eutrophication as outsider impacts.

The results are summarised in **Table 6**. The most significant impact values are printed in bold. Be aware that the results are based largely on general data and European normalization standards and thus function as indicators of the magnitude of the impacts. The exact results should not be quoted for decision making.

Land Use. Palm oil plantation land use is a heavily debated subject concerning in particularly biodiversity and global warming. How big is the impact of oil palm plantations on the clearance of jungle and how can the actual impact be assessed?

Table 6: Weighted values from the default and optimised system

Impact /damage category	Unit	Plantation	Transport	Mill	System	Optimised Plantation	Optimised Transport	Optimised Mill	Optimised System
Carcinogens	Pt	0.65	0.07	–0.11	0.61	0.40	0.09	–0.29	0.20
Resp. organics	Pt	0.04	0.02	$-6.4 \cdot 10^{-4}$	0.05	0.03	$1.6 \cdot 10^{-3}$	$-1.7 \cdot 10^{-3}$	0.03
Resp. inorganics	Pt	**10.9**	**5.0**	**13.8**	**29.8**	**8.04**	0.59	**6.74**	**15.40**
Climate change	Pt	**2.7**	0.81	–0.31	**3.2**	**1.77**	0.15	–0.81	**1.10**
Radiation	Pt	$8.1 \cdot 10^{-4}$	$3.2 \cdot 10^{-4}$	–	$1.1 \cdot 10^{-3}$	$5.8 \cdot 10^{-4}$	$2.0 \cdot 10^{-3}$	–	$2.5 \cdot 10^{-3}$
Ozone layer	Pt	$7.2 \cdot 10^{-3}$	$5.4 \cdot 10^{-3}$	$-1.0 \cdot 10^{-4}$	0.01	0.01	$6.0 \cdot 10^{-4}$	$-2.8 \cdot 10^{-4}$	$5.5 \cdot 10^{-3}$
Human Health	**Pt**	**14.3**	**5.9**	**13.4**	**33.7**	**10.24**	**0.83**	**5.63**	**16.73**
Ecotoxicity	Pt	0.32	0.66	–0.05	0.93	0.20	0.11	–0.12	0.19
Acidification/ Eutrophication	Pt	**1.8**	0.73	0.22	**2.7**	**1.31**	0.07	0.13	**1.50**
Land use	Pt	0.07	0.04	–	0.11	0.05	0.21	–	0.26
Ecosystem Quality	**Pt**	**2.1**	**1.4**	**0.2**	**3.7**	**1.56**	**0.39**	**$6.0 \cdot 10^{-3}$**	**1.95**
Minerals	Pt	$5.6 \cdot 10^{-3}$	$3.5 \cdot 10^{-3}$	–	$9.1 \cdot 10^{-3}$	$4.0 \cdot 10^{-3}$	0.01	–	0.01
Fossil fuels	Pt	**19.5**	**6.2**	**–1.9**	**23.8**	**12.90**	0.76	**–5.13**	**8.52**
Resources	**Pt**	**19.5**	**6.2**	**–1.9**	**23.8**	**12.90**	**0.77**	**–5.13**	**8.53**
Total	**Pt**	**36.0**	**13.5**	**11.6**	**61.3**	**24.70**	**1.99**	0.51	**27.2**

Most significant values (>1 Pt) and damage category values are marked in bold

The vast areas now covered by oil palm plantations used to be covered by jungle, but who are to blame? Is the jungle actually being cleared in order to plant oil palms or was the jungle cleared in advance due to rubber plantations and timber logging? Both statements are being strongly argued by the debate opponents respectively.

One important aspect concerning environmental impacts is the manner in which the land is prepared for the plantation. Whether the area is covered by primary forest (jungle) or secondary forest (cultivated or formerly cultivated) the easiest way of clearing the land is by burning. This method is both highly polluting and carries the risk of the fire spreading. The clearing of land must be done in a controlled manner. Both Malaysia and Indonesia (the second largest palm oil producer in the world) have introduced zero burning policies, but frequent forest fires in especially Indonesia still cover large regions in haze and prove that stricter monitoring and higher fines must be introduced.

Primary jungle will contain app. 250 ton C per ha, whereas a mature palm oil plantation will contain app. 100 ton C per ha (Lasco 2002). The 150 ton of lost C amounts to about 950 ton of CO_2 assuming that all carbon is lost as CO_2. In comparison the total CO_2 emissions from production of CPO from one hectare during its lifetime amounts to no more than 2000 ton and even less with environmental investments. Replacing primary jungle with palm oil plantations is thus a significant global warming contribution in the palm oil CO_2 budget. It must, however, also be included in the debate whether the palm oil estate is converted into farmland, urban area or left as secondary forest after closure of the plantation. If secondary forest is allowed to grow and thus take up CO_2, the overall global warming effects will lessen. If other farm use or urban area takes over it could be debated whether the cultivation would have occurred anyway on expense of primary jungle if the plantation had not already been established.

If plantation land use was to be included quantitatively in the LCA, the lifecycle of the land would have to be assessed. That What was on the land originally? what was there before the plantation? what would have been there if the plantation had not emerged? what will be there after the plantation? and what methods are used in the transitions between the life cycle stages (burning, controlled logging, etc.)? Hopefully it is only a matter of time before such a study is undertaken in Malaysia.

Whatever the background of the plantation area is, the fact is that plantations already present monoculture ecosystems covering more than 11% of Malaysia and prevent these vast land areas from returning to a more diverse secondary forest. As such the debates must continue in order to prevent uncontrolled expansion of plantations and thus secure the biodiversity in Malaysia.

Rather than expanding the areas used for plantations, investments could be aimed towards optimising the yield and the oil extraction from the existing plantations. Research has shown that the potential oil production is more than 5 ton CPO per hectare, which is still far from reached by the Malaysian palm oil industry, which is struggling at an average of 4 ton CPO per hectare. Resources should thus be spent in the areas of educating farmers and optimising mill technologies.

Table 7: Oil yields from the five most produced oil crops

Oil	Oil yield [kg/ha]
Palm oil	4000 [a]
Rapeseed oil	1000
Groundnut oil	890
Sunflower oil	800
Soyabean oil	375

<http://journeytoforever.org/biodiesel_yield.html>
[a] The source says 5000, but the Malaysian value used for this assessment is 4000 kg/ha

There is a general consensus between the opposing sides that palm oil is indispensable at present time. Oil is an important ingredient in countless products and alternative oils carry the same or worse environmental impacts with them. In fact, palm oil has by far the highest oil yield per hectare among vegetable oil crops and is thus far more land use effective. **Table 7** lists the five most produced oil crops and their respective yields of oil per hectare.

7 Recommendations

7.1 Introduction of LCA/LCM as a tool for environmental assessments/management in the palm oil industry

Conducting an LCA for in a company means compiling all inputs and outputs into a transparent inventory. This provides the company with an excellent overview of areas in which material and thus economic savings can be made for the good of both environment and the company finances.

Including the life cycle perspective of all processes makes it possible to get an overview of whether inputs could be substituted by less polluting materials. Computing the LCI results and retrieving impact scores will determine how the pollution affects humans and environment and provides a comparable impact value that may be used in marketing in a global market that is starting to demand environmentally conscious production. Managing the company through life cycle management (LCM) thus has several advantages.

Several NGOs are putting pressure on palm oil importers to demand cleaner production from the producers. In promoting palm oil as a 'green' product Malaysia may gain competitive advantages not only towards other palm oil producers, but towards other vegetable oils (like soy or rape seed) as well. Generally integrated environmental improvements will often prove to lessen expenses on longer terms and thus provide direct economic incentives on top of the competitive advantages.

7.2 Preparation of Malaysian normalization and weighting standards

In order to be able to carry out precise LCAs in Malaysia in the future it is important to apply Malaysian normalization and weighting standards and improve the availability of life cycle related input-output data.

The above matters should be addressed by a panel of local experts with the aim of preparing Malaysian normalization and weighting standards. In order to create Malaysian normalization standards, a large scare inventory must be made for Malaysia including industries, households, transportation and public/governmental/commercial institutions to map out the full environmental impacts from the country. It is also important that the government put pressure on the industries to record and make available their input-output inventories.

7.3 Incentives for introduction of cleaner technology

In order for the industry to make cleaner technology investments it is important that incentives are visible. The government and industry representatives must therefore agree on e.g. increased tariffs on electricity and diesel and/or financial support for cleaner technology investments.

Campaigns must also be made in order to raise the awareness among the industries that the world market is starting to set demands for environmentally conscious production and that cleaner technology investments will most often make the money back within a relatively short amount of years due to reduced use of energy and input materials.

7.4 LCA on plantation land use in Malaysia

In order to prepare holistic LCAs the plantation land use should be included in the assessment. Academic studies must thus be conducted to prepare templates for land use LCAs in Malaysia.

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